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THE DESIGN AND ANALYSIS OF SALMONID TAGGING STUDIES IN THE COLUMBIA BASIN

VOLUME I: ASSESSMENT OF TEMPORAL TRENDS IN DAILY SURVIVAL ESTIMATES OF SPRING CHINOOK, 1994 - 1996

Technical Report

DOE/BP-02341-7

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THE DESIGN AND ANALYSIS OF SALMONID TAGGING STUDIES IN THE COLUMBIA BASIN

VOLUME I

Assessment of Temporal Trends in Daily Survival Estimates

of Spring Chinook, 1994-1996

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PREFACE

This report is the first of a series of reports produced by the University of Washington for the Bonneville Power Administration under the title of “The Design and Analysis of Salmonid Tagging Studies in the Columbia Basin”, with the purpose of offering new and alternative methods to analyzing data from tagging studies in the Columbia Basin. Project 8910700, Epidemiological Survival Methods, was developed to provide statistical guidance on design and analysis of PIT-tag (Passive Integrated Transponder) survival studies to the Northwest fisheries community. Studies under this project have determined the statistical feasibility of conducting PIT-tag smolt survival studies, assessed analytical capabilities for analyzing the tagging experiments, and made recommendations on study design. As PIT-tag capabilities developed and research interests increased, the project has been instrumental in maintaining the statistical capabilities for designing and analyzing tagging studies to meet these expanded objectives.

In this report the possibility of detecting temporal trends in the survival estimates for 1994, 1995 and 1996 PIT-tagged spring smolt chinook is analyzed and discussed. Simple linear regressions between survival estimates and date of PIT-tag release and spline analysis were used to assess increasing and/or decreasing trends in survival. The analysis was motivated by the managerial need for adequate measures of smolt survival that enable the detection of changes in survival during and across seasons. Survival estimates for specific groups of PIT-tagged fish at particular times and locations during the outmigration are normally obtained using the statistical computer program *SURPH.1* (SURvival with Proportional Hazards). Depending on the sampling effort across the migration period, *SURPH.1* provides a series of daily survival estimates and associated standard errors. Often these daily survival estimates oscillate around some identifiable average value, but they may also show trends (e.g., decrease in survival with the progression of the season). This report illustrates some ways of dealing with these cases.

ABSTRACT

Daily survival estimates (*SURPH.1* daily estimates) from the tailrace of Lower Granite Dam (LGR) to that of Lower Monumental Dam for 1994, 1995 and 1996 spring chinook smolt not only oscillate around their annual average, but they also suggest apparent trends when displayed against LGR release day. Simple linear regressions between survival estimates corresponding to the last 50% of the runs and the day of release showed negative slopes, indicative of decreasing survival in 1994, 1995 and 1996. However, regressions between the last 15 or 30 survival estimates of each year and their corresponding days of release did not always show negative slopes. The presence of a significant negative slope, appeared to be associated to the timing (i.e., cumulative percentage of the runs) of the last 15 or 30 survival estimates, and the size of the release groups used in the survival estimations. In fact, spline analyses showed that slopes changed (normally from positive to negative) near the end of the outmigration. On the other hand, simulations showed that *SURPH.1* survival estimates for small releases (e.g. 50 fish) are likely to be positively biased. Thus the negative trends in survival detected for the last portions of the 1994, 1995 and 1996 runs cannot be explained by estimation bias in the survival estimates, although positive estimation bias might have complicated the detection of a negative trend for the last portions of the 1995 run.

EXECUTIVE SUMMARY

Objectives

In the present report, we analyzed and discussed the possibility of detecting temporal trends in the survival estimates for 1994, 1995 and 1996 spring chinook. We used smolt survival estimates (*SURPH.1* daily estimates) from the tailrace of Lower Granite Dam (LGR) to that of Lower Monumental Dam (LMN) as our basic data, to which various regression and simulation techniques were applied to assess the possible influence of the number and quality of data in detecting significant linear trends.

Results

In simple linear regressions between *SURPH.1* survival estimates and the date of PIT-tag releases (in days of the year) the slope coefficient is a measure of temporal trend in survival. Regressions between survival estimates corresponding to the last 50% of the runs showed negative slopes in 1994, 1995 and 1996, although the slopes were significant only for 1994 and 1996. On the other hand, regressions between the last 15 or 30 survival estimates of each year and their corresponding days of release did not always show negative slopes.

The presence of a significant negative slope, that indicates a decreasing trend in survival, appeared to be associated to the timing (i.e., cumulative percentage of the runs) of the last 15 or 30 survival estimates, and the size of the release groups used in the survival estimations. Moreover, spline analyses showed that slopes changed (normally from positive to negative) near the end of the outmigration. In 1994, the slope became negative on 22 May when 97.41% of the run had passed Lower Granite Dam. In 1995, this changed also occurred on 22 May but for 92.81% of the run detected. Finally, in 1996, the change in slope occurred on 20 May when 92.03% of the run had passed the dam.

Finally, simulations showed that *SURPH.1* survival estimates for small releases (e.g. 50 fish) are likely to be positively biased. Thus the negative trends in survival detected for the last portions of the 1994, 1995 and 1996 runs cannot be explained by estimation bias in the survival estimates. However, positive estimation bias might have be responsible for the few large survival estimates obtained from the last 1995 releases, that complicated the detection of a negative trend for the last portions of the 1995 run.

Management implications

The occurrence of negative trends in survival in the last portions of the 1994, 1995 and 1996 runs in the LGR-LMN reach may lead to further research to determine the spread of this phenomenon, as well as the factor or factors causing it, which may eventually lead to its control.

Recommendations

In future years it would be advisable to increase the number of tagged fish released during the last weeks of the run.

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1. INTRODUCTION

In 1993, the National Marine Fisheries Service (NMFS), in collaboration with the University of Washington, started marking salmon smolt with PIT-tags, or passive integrated transponders (Prentice et al., 1990a, b, c), to estimate survival and investigate the dynamics of smolt migration (Iwamoto et al., 1994; Muir et al., 1995, 1996). Survival estimates for specific groups of tagged fish at particular times and locations during the outmigration are obtained using the statistical computer program *SURPH.1* (SURvival with Proportional Hazards), developed at the University of Washington (Smith et al., 1994). This program extends the standard single-release models (Cormack, 1964; Jolly, 1965; Seber, 1965) to allow simultaneous analysis of release-recapture PIT-tag data from multiple release groups.

Since 1993 PIT-tagging effort has increased, allowing the study of possible temporal trends in *SURPH.1* daily survival estimates for particular species, runs and locals. Survival estimates reported in recent papers (Skalski,1998; Skalski et al, 1998) suggest such temporal trends for the 1994, 1995 and 1996 spring chinook runs.

In the present report, we analyzed and discussed the possibility of detecting temporal trends in the survival estimates for 1994, 1995 and 1996 spring chinook. We used smolt survival estimates (*SURPH.1* daily estimates) from the tailrace of Lower Granite Dam to that of Lower Monumental Dam as our basic data, to which various regression and simulation techniques are applied to assess the possible influence of the number and quality of data in detecting significant linear trends.

2. MATERIALS AND METHODS

2.1 Data

The study is based on PIT-tagged spring yearling chinook salmon smolts that were tagged anywhere in the Snake River Basin at or above Lower Granite Dam (LGR) in 1994, 1995 and 1996. Both hatchery and wild chinook were used.

PIT-tagged fish passing through LGR from upriver release sites and fish tagged and released from LGR on the same day formed a daily release group. The fate of these fish was followed by subsequent detections at Little Goose Dam (LGS), Lower Monumental Dam (LMN) and the final detection site, McNary Dam (MCN). Capture histories consisting of 1's and 0's (1 indicating detection) were thus obtained for each fish in the release groups. The capture histories were then used in Program *SURPH.1* to obtain survival estimates and capture probabilities for each release group.

For LGR release groups *SURPH.1* provided two direct survival estimates: 1) the survival from the tailrace of LGR dam to the tailrace of LGS dam, hereinafter termed S_1, and 2) the survival from the tailrace of LGS dam to the tailrace of LMN dam, hereinafter termed S_2. A third indirect survival estimate for the reach LGR-LMN ($S_{1.2}$) was calculated as the product of S_1 and S_2. *SURPH.1* also furnished two capture or detection probability estimates: 1) the capture probability at LGS dam, termed p_1, and 2) the capture probability at LMN dam, termed p_2. Finally, *SURPH.1* gave estimates for the probability that a fish has of surviving from the tailrace of LMN dam to the tailrace of MCN dam and being detected at MCN (i.e., λ).

The size of LGR release groups varied over the course of the migration season. Groups for the 1994 spring migration ranged from 3 to 2921 fish. Group sizes varied from 2 to 9355 fish in 1995, and from 11 to 5555 fish in 1996. Figures 1-3 show the survival estimates for 1994, 1995 and 1996 spring chinook salmon smolts in the LGR-LMN reach ($S_{1.2}$) with symbols indicating the size of the release groups. Most of the groups released during the first days of the runs and during the last days of the run consisted of less than 50 fish (open circles in Fig. 1-3). The survival estimates for these groups as well as those for groups with 50 to 299 fish (squares in Fig. 1-3) suggest a clear decrease in survival for the lower half of the 1994 and 1996 runs, and an apparent increase in survival for the lower portion of the 1995 run.

2.2 Detection of temporal trends through linear regression

We used simple linear regression models to asses temporal trends in the survival of 1994, 1995 and 1996 spring chinook in the LGR-LMN reach ($S_{1.2}$). In these models:

$$S_i = \alpha + \beta D_i + \varepsilon_i \qquad (1)$$

Figure 1: Plot of daily survival estimates of 1994 spring chinook smolt from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam, along with the cumulative arrival distribution at Lower Granite Dam (green line). Symbols indicate the number of fish in the release groups that the survival estimates were based upon.

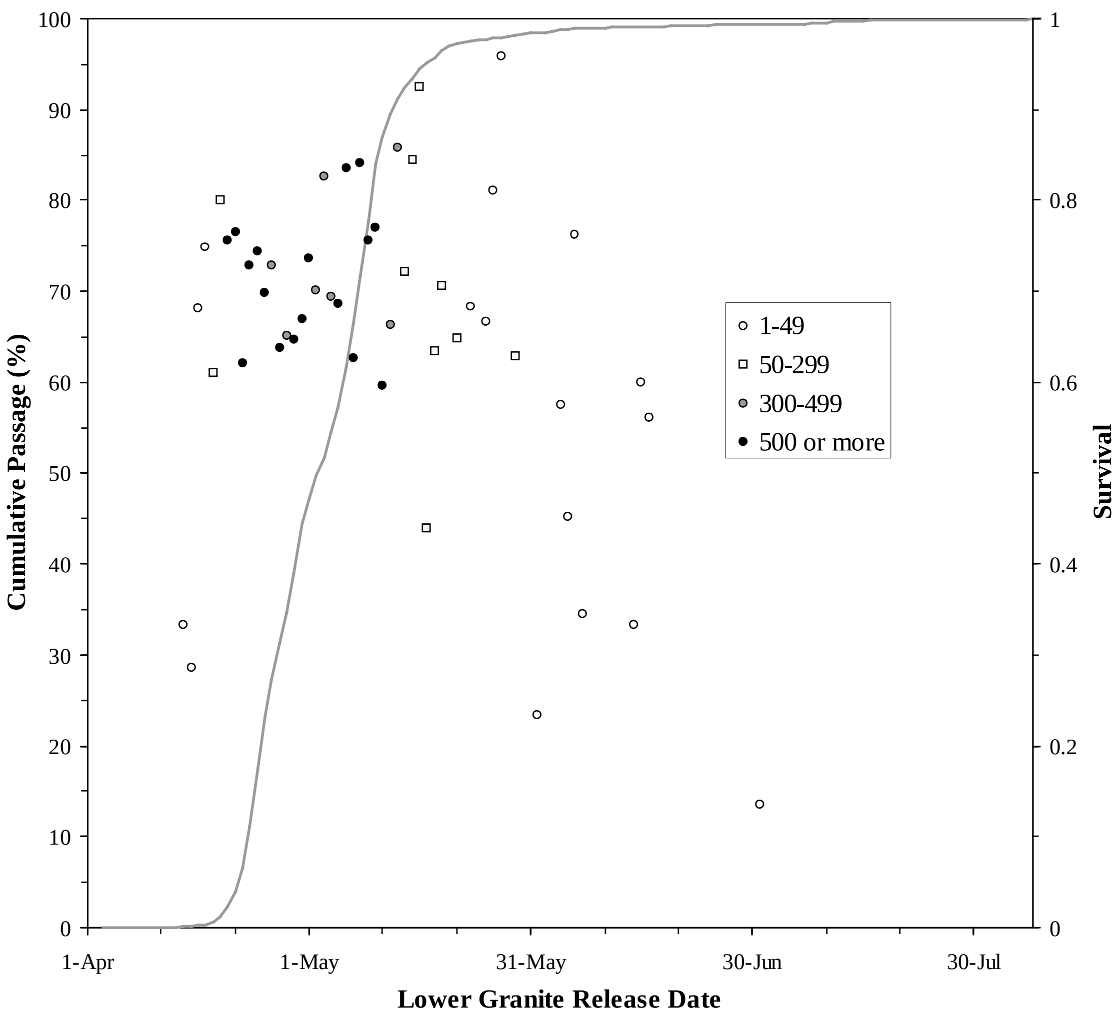


Figure 2: Plot of daily survival estimates of 1995 spring chinook smolt from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam, along with the cumulative arrival distribution at Lower Granite Dam (green line). Symbols indicate the number of fish in the release groups that the survival estimates were based upon.

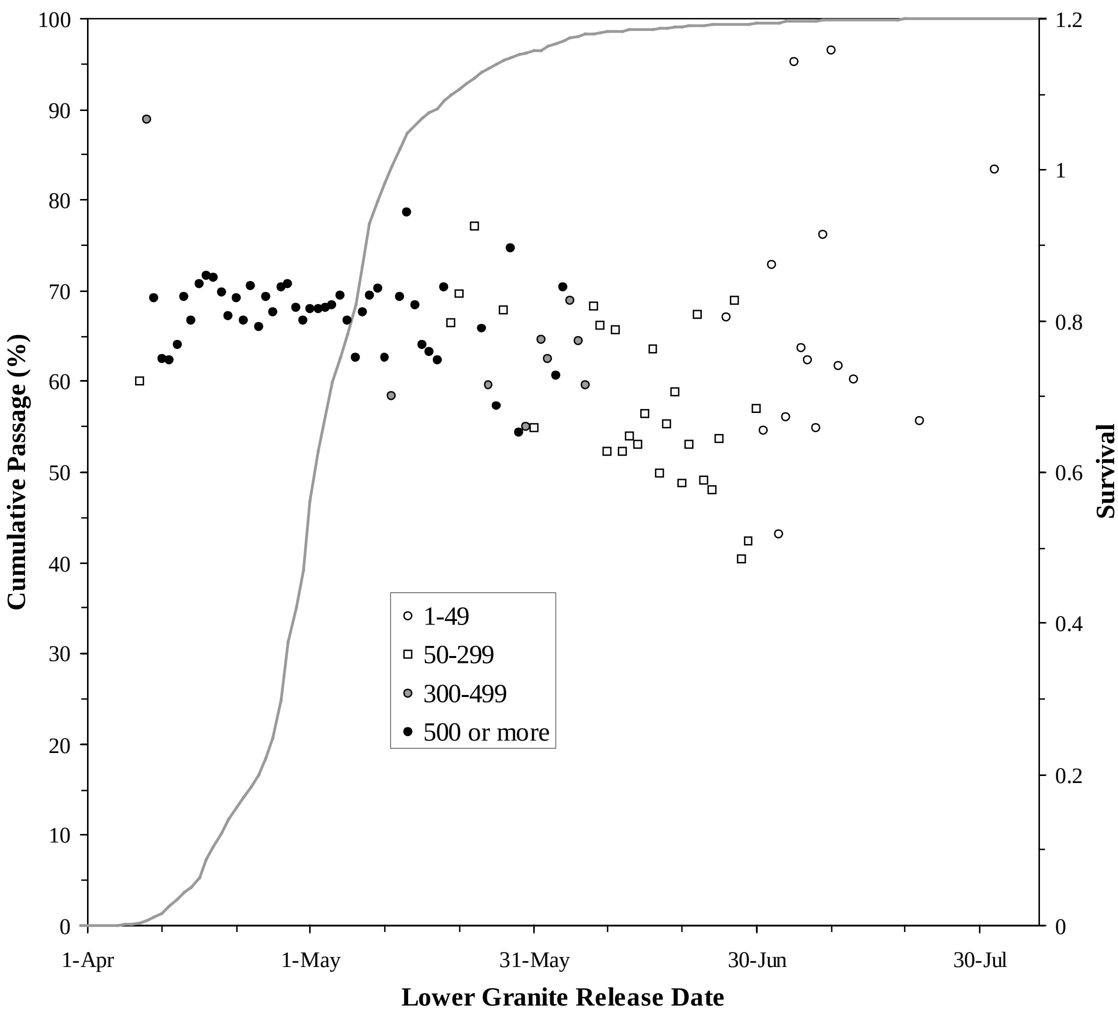
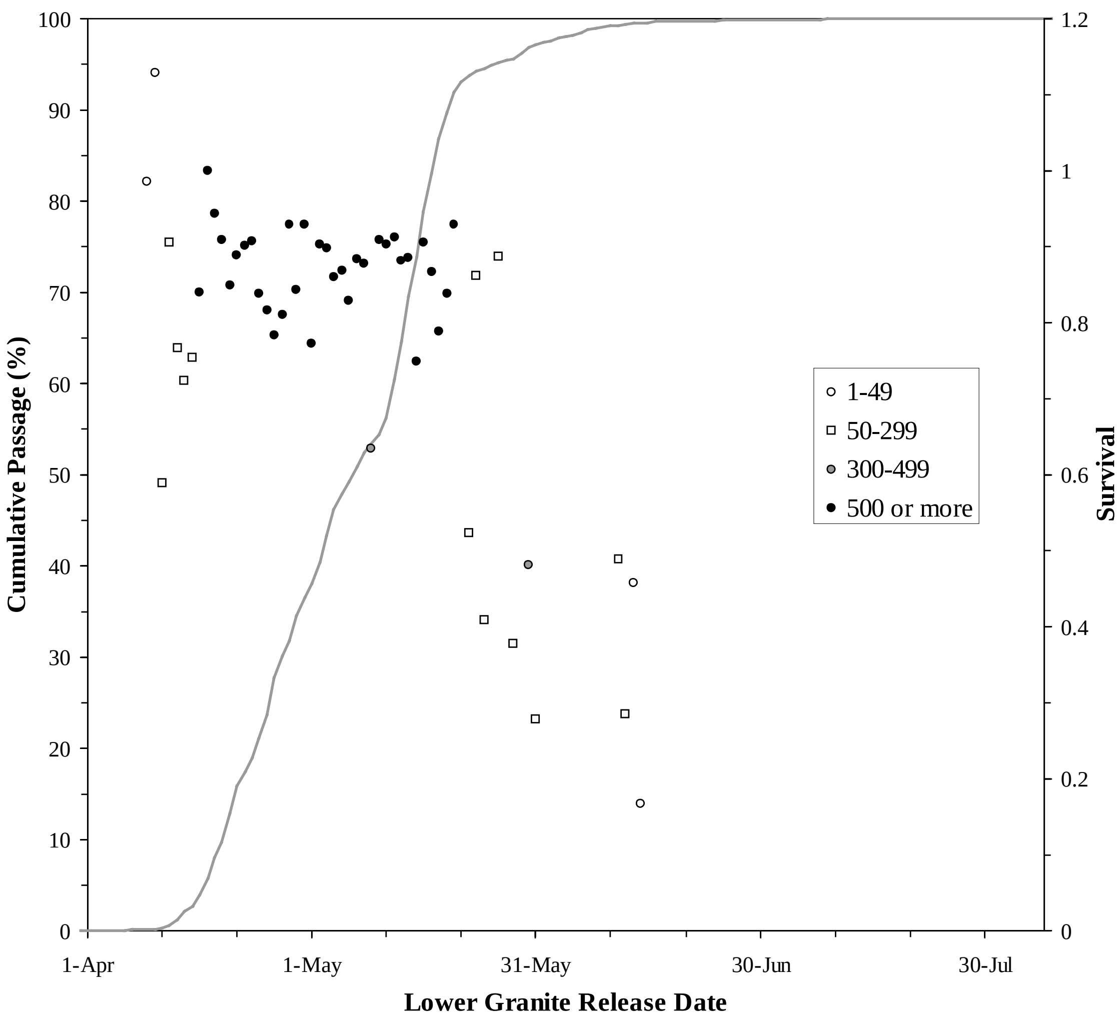


Figure 3: Plot of daily survival estimates of 1996 spring chinook smolt from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam, along with the cumulative arrival distribution at Lower Granite Dam (green line). Symbols indicate the number of fish in the release groups that the survival estimates were based upon.



S_i is the product of *SURPH.1* survival estimates S_1 and S_2 for group i released on day D_i, expressed in Julian days. The parameter estimate $\hat{\beta}$, or slope, determines the temporal trend. If $\hat{\beta}$ is positive and significant (α-level = 0.05) we may infer a linear increase in survival during the studied period. A linear decrease is otherwise inferred if $\hat{\beta}$ is negative and significant. We used regression model (1) in two different ways.

First, for each of the three years we applied model (1) to groups of 5, 15 and 30 consecutive survival estimates. These groups were defined as moving windows starting with the last estimate, and moving towards the first estimate, one at a time. Thus, for example the 54 survival estimates for 1994 provided 50 groups of 5, 40 of 15, and 25 of 30 $S_{1.2}$ estimates. The number of groups with significant $\hat{\beta}$'s for each window category (5, 15 and 30) will suggest which is the best data range to detect temporal trends given the variability of the present data.

Second, we applied model (1) to the $S_{1.2}$ survival estimates for the upper and lower halves of the 1994, 1995 and 1996 runs. We used the day at which the cumulative passage index at LGR equaled 0.5 to split the data. For each half linear regressions were estimated using *a)* all the survival estimates, *b)* all the survival estimates based on release groups with 50 or more fish, *c)* the survival estimates based on groups with 300 or more fish, and finally *d)* only the survival estimates based on release groups with 500 or more fish. This approach helped us identify what type of trend (increasing or decreasing), if any, was associated to the upper and lower halves of the runs, and to determine the importance of the different release sizes in the estimates of survival.

2. 3 Spline analysis

In the previous regression analyses we tried to detect negative trends in the last portion of the runs by moving windows of fixed sizes or by arbitrarily splitting the data sets in two halves. However, trends can also be detected by fitting spline regression lines to a data set. The spline regression, a generalization of piecewise linear regressions (Neter et al., 1985, pages 346-348), finds two separate lines, joined at a common point, that best fit the data.

The equation used in spline analysis was:

$$S_i = \alpha + \beta D_i + \gamma\left(D_i - D_K\right)X_i + \varepsilon_i \qquad (2)$$

where S_i is the *SURPH.1* $S_{1.2}$ survival estimate for group i released on day D_i, expressed in Julian days (D_i = 1, 2, …, 365), and α, β and γ are the linear regression parameters. They determine the intercepts and slopes of the regression lines corresponding to each portion of the data, such that $S_i = \alpha + \beta D_i + \varepsilon_i$ and $S_i = \left(\alpha - \gamma D_K\right) + \left(\beta + \gamma\right)D_i + \varepsilon_i$, for the first and last portion of the data. The parameter D_K determines the point where the data are splined. The dummy variable X takes value 1 if $D_i > D_K$ and 0 otherwise.

For each data set, D_K was set equal to each possible value within the range of variable D, and model equation (2) was minimized through linear least squares. Finally, the spline solution was the set of D_K, $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\gamma}$ that provided the smallest residual sum of squares.

2. 4 Assessment of bias on survival estimates

Because the size of LGR release groups varied considerably along and among the runs, and groups with small number of tagged fish may produce biased survival estimates that may in turn affect the regression results, we performed a series of simulations to assess the expected bias in *SURPH.1* survival estimates. For six parameter combinations we simulated 1000 groups of 50 and 500 capture histories. The simulation consisted of a series of Bernoulli trials that took the values assigned to S_1, S_2, p_1, p_2 and λ as their probabilities of success. Figure 4 diagrams the simulation study used to investigate estimation bias. The six parameter combinations were:

1) S_1 = 0.88, S_2 = 0.9, $p_1 = p_2 = \lambda$ = 0.4,

2) S_1 = 0.88, S_2 = 0.9, $p_1 = p_2 = \lambda$ = 0.2,

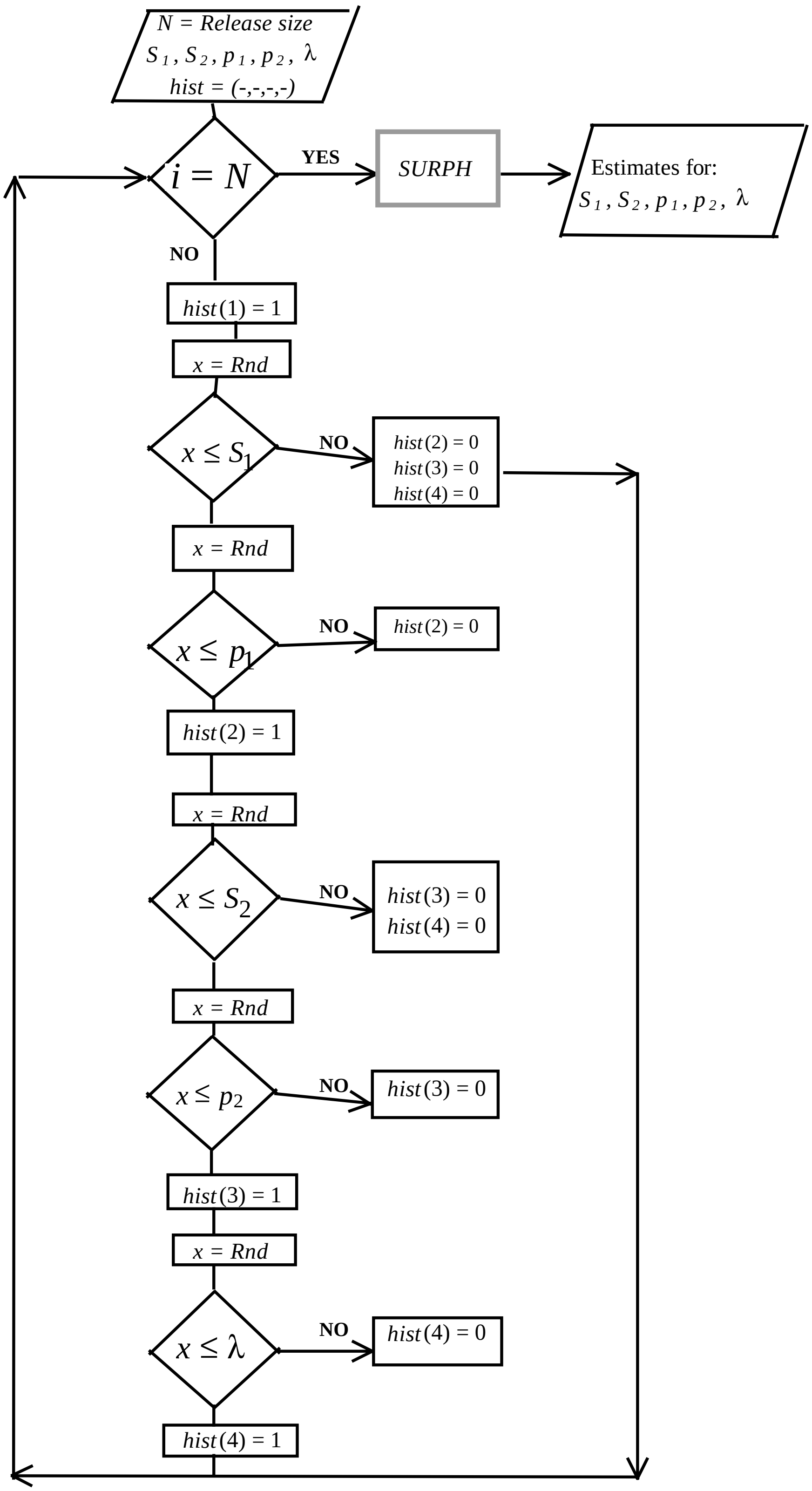
3) S_1 = 0.82, S_2 = 0.78, $p_1 = p_2 = \lambda$ = 0.4,

4) S_1 = 0.82, S_2 = 0.78, $p_1 = p_2 = \lambda$ = 0.2,

5) S_1 = 0.64, S_2 = 0.51, $p_1 = p_2 = \lambda$ = 0.4 and

6) S_1 = 0.64, S_2 = 0.51, $p_1 = p_2 = \lambda$ = 0.2.

Figure 4: Diagram of the simulation algorithm used to generate capture histories and their *SURPH.1* estimates.



Once the 1000 estimates were obtained, the expected biases were calculated as the differences between the averages of the parameter estimates and the parameter values.

3. RESULTS

3.1 Linear regressions

The results from applying regression model (1) to the moving windows of size 5, 15 and 30 can be found in Appendices A1-A9. Table 1 summarizes these results. As the range of the regressions increases from 5 to 30 the percentage of regressions with significant slopes increases for the three years. Moreover, the 1994 and 1996 survival estimates corresponding to later portions of the runs (8 May-1 July 1994, and 29 April-14 June 1996), when combined in groups of 15 or 30, generally provided significant negative slopes (Appendices A2, A3, A8 and A9). This suggests the existence of decreasing temporal trends in survival. However, the later portions of the 1995 run, 4 July-1 August 1995, did not show significant negative slopes. On the contrary, the slopes were positive. Only survival estimates corresponding to more central portions of the run, 19 May-3 July 1995 showed significant negative trends (Appendices A5 and A6).

Tables 2-3 show the results for the regressions performed on the $S_{1.2}$ survival estimates for the first and second halves of the 1994, 1995 and 1996 runs. We could not infer the existence of any particular temporal linear trend for the first halves of the runs because the regressions did not have significant slopes no matter what release groups were considered in the analyses (Table 2). For the second halves of the 1994, 1995 and 1996 runs, however, decreasing temporal trends in survival may be inferred. When survival estimates for all release groups were used, only the regressions for the second halves of 1994 and 1996 runs showed significant negative slopes (Table 3). On the other hand, when survival estimates for release groups with 50 or more fish were used, significant negative slopes were obtained for the second halves of the 1995 and 1996 runs. Finally, significant negative slopes were not detected when only the $S_{1.2}$ survival estimates for release groups with 300 or more fish were used (Table 3). Thus, the significancy of these negative trends appeared to depend upon survival estimates of small-sized release groups (e.g., release groups with less than 50 fish).

Table 1: Significant (α = 0.05) temporal trends (slope) for windows of 5, 15 and 30 consecutive survival estimates of 1994-96 spring chinook smolt.

Year	Sampled period	Number of estimates	Size of combinations	Regressions	
				Total	Significant
94	14 Apr - 1 Jul	54	5	50	0
			15	40	3
			30	25	4
95	8 Apr - 1 Aug	98	5	94	3
			15	84	8
			30	69	20
96	9 Apr - 14 Jun	54	5	50	3
			15	40	5
			30	25	5

Table 2: Results of regression analyses between daily survival estimates ($S_{1.2}$) for the first half of the outmigration of spring chinook salmon smolts and release date. All survival estimates correspond to the reach extending from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam.

		Releases							
Year	Day of Year	Number	Size	Intercept	SE	Slope	SE	P-value	r^2
94	105-123	19	≥1	-0.4750	0.6015	0.0100	0.0053	0.0760	0.1736
		15	≥50	1.0172	0.4062	2.5042	0.0264	0.4483	0.0449
		13	≥300	1.1979	0.4172	-0.0043	0.0036	0.2567	0.1151
		11	≥500	1.3533	0.4951	-0.0056	0.0042	0.2168	0.1639
95	99-122	24	≥1	0.8434	0.2115	-0.0002	0.0019	0.9270	0.0004
		24	≥50	0.8434	0.2115	-0.0002	0.0019	0.9270	0.0004
		23	≥300	0.9874	0.2144	-0.0014	0.0019	0.4656	0.0256
		22	≥500	0.6546	0.1177	0.0015	0.0011	0.1807	0.0877
96	100-127	28	≥1	0.9165	0.2700	-0.0005	0.0024	0.8453	0.0015
		26	≥50	0.4969	0.2473	0.0031	0.0022	0.1670	0.0780
		21	≥300	1.2056	0.2321	-0.0028	0.0020	0.1671	0.0980
		21	≥500	1.2056	0.2321	-0.0028	0.0020	0.1671	0.0980

Table 3: Results of regression analyses between daily survival estimates ($S_{1.2}$) for the second half of the outmigration of spring chinook salmon smolts and release date. All survival estimates correspond to the reach extending from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Year	Day of Year	Releases Number	Releases Size	Intercept	SE	Slope	SE	P-value	r^2
94	124-183	35	≥1	1.8111	0.4691	-0.0076	0.0033	0.0252	0.1429
		21	≥50	-0.2009	1.0778	0.0074	0.0080	0.3702	0.0425
		11	≥300	1.0149	1.2006	-0.0021	0.0093	0.8250	0.0057
		7	≥500	1.9883	2.5177	-0.0098	0.0195	0.6385	0.0476
95	123-214	74	≥1	1.0134	0.1728	-0.0015	0.0011	0.1658	0.0265
		59	≥50	1.4307	0.2307	-0.0044	0.0015	0.0053	0.1283
		31	≥300	1.0549	0.1405	-0.0019	0.0010	0.0635	0.0635
		24	≥500	1.0155	0.1915	-0.0016	0.0014	0.2634	0.0565
96	128-166	26	≥1	3.1691	0.5838	-0.0171	0.0041	0.0003	0.4240
		23	≥50	2.9121	0.8519	-0.0153	0.0061	0.0203	0.2309
		16	≥300	1.0653	1.3987	1.0653	1.3987	0.8953	0.0013
		14	≥500	-1.3064	1.6576	0.0165	0.0122	0.2032	0.1312

In summary, the regression between survival estimates corresponding to the last 50% of the runs and Day of release showed negative slopes in 1994, 1995 and 1996, although the slopes were significant only for 1994 and 1996 (Table 3). On the other hand, regressions between the last 15 or 30 survival estimates of each year and their corresponding Days of releases did not always show negative slopes (Appendices A2, A3, A5, A6, A8 and A9). The presence of a negative slope, moreover of a significant one, appears to be associated to the timing (i.e., cumulative percentage of the runs) of those 15 or 30 survival estimates. For example, the last 15 survival estimates of 1994 and 1996 produced significant negative slopes (Appendices A2 and A8). These estimates were obtained after 22 May 1994, and 17 May 1996, and corresponded to the last 2.43% and 13.25% of the 1994 and 1996 runs. Fourteen of the 1994's survival estimates came from releases of less than 50 fish, but only two of 1996's estimates came from such small releases. On the other hand, the last 15 survival estimates of 1995, corresponding to groups released after 30 June (the last 0.52% of the 1995 run) produced a positive, albeit not significant, slope. Fourteen of these survival estimates also came from releases with less than 50 fish. (Appendix A5). However, when the regression was performed with survival estimates corresponding to groups that had more than 50 fish and were released from 7 to 21 June 1995 (respectively, the last 1.74% and 0.78% of the run), the slope became negative and statistically significant.

3.2 Splines

Figures 5-7 show the splines estimated for the 1994, 1995 and 1996 survival estimates $\hat{S}_{1.2}$. For 1994, we estimated an initial increase in survival until 22 May, followed by a pronounced decrease (Fig. 5). The equations for these two regression lines were $\hat{S}_{1.2} = -0.2164 + 0.0076D$ and $\hat{S}_{1.2} = 3.4121 - 0.0178D$, where D is the day of the year (D = 1, 2, …, 365). The coefficient of determination for the whole fit was $r^2 = 0.28$. The cumulative percentage of the run corresponding to 22 May was 97.41%. The spline calculated for 1996 data (Fig. 7) indicates a barely perceptible decrease in survival until 20

Figure 5: Spline (red line) for daily survival estimates of 1994 spring chinook smolt from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam, along with the cumulative arrival distribution at Lower Granite Dam (green line). Symbols indicate the number of fish in the release groups that the survival estimates were based upon.

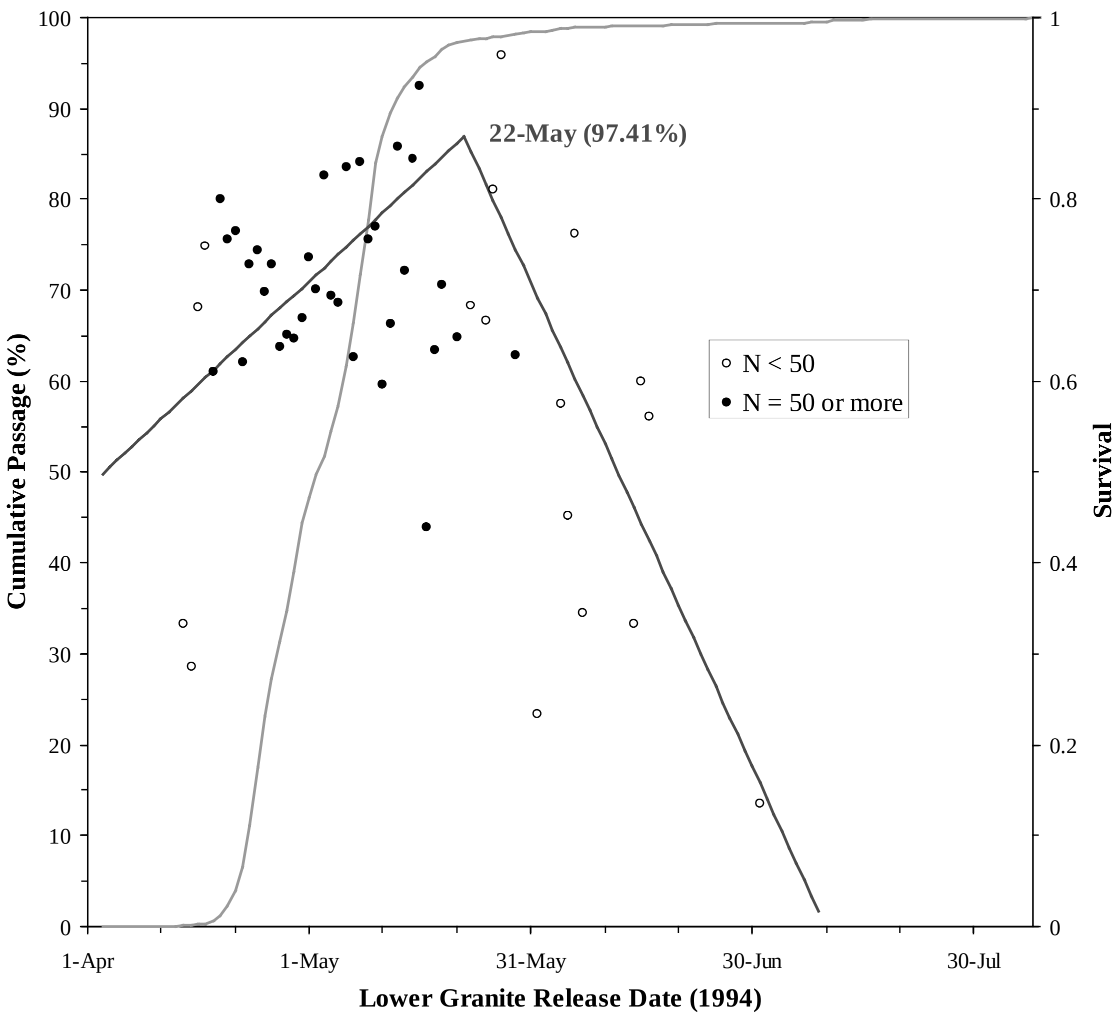


Figure 6: Spline (red line) for daily survival estimates of 1995 spring chinook smolt from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam, along with the cumulative arrival distribution at Lower Granite Dam (green line). Symbols indicate the number of fish in the release groups that the survival estimates were based upon.

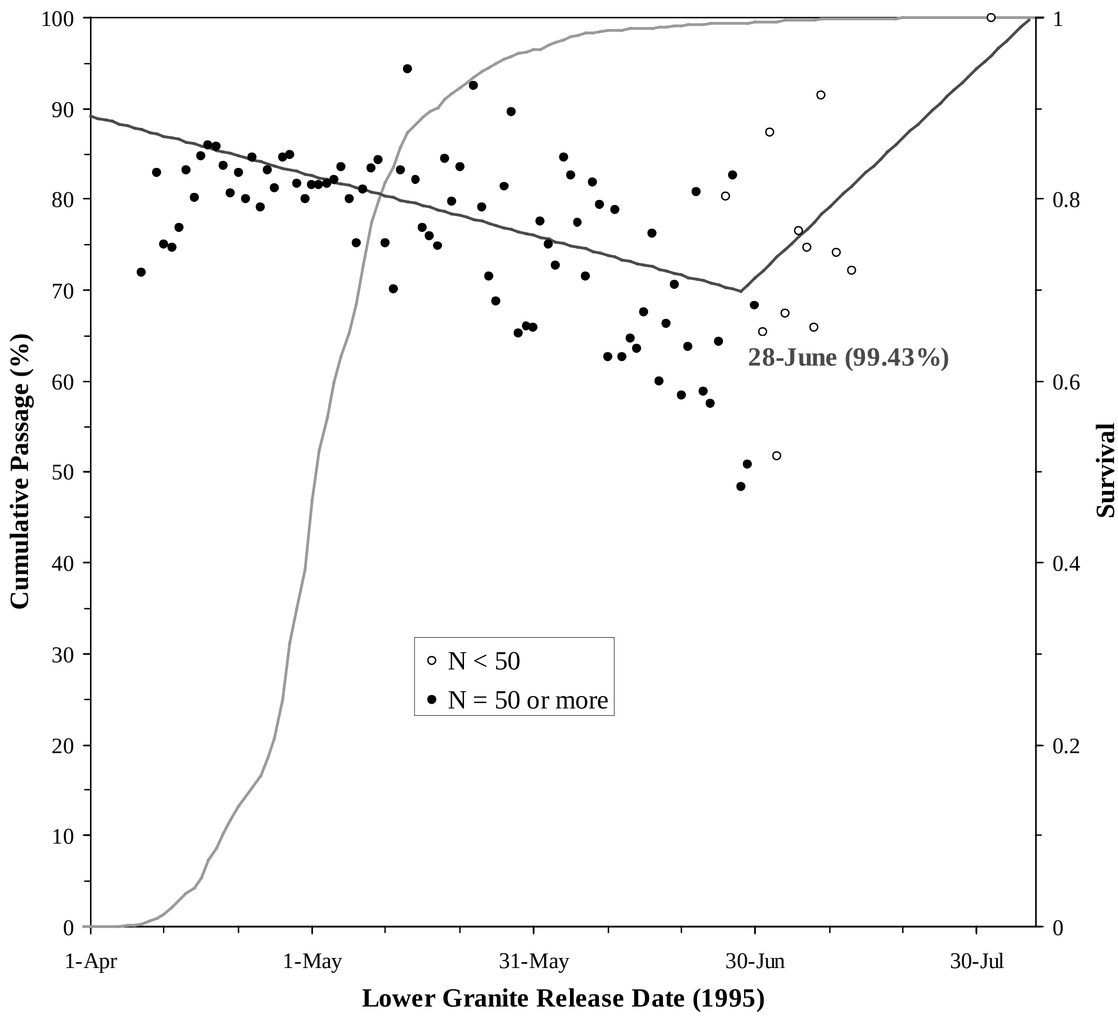
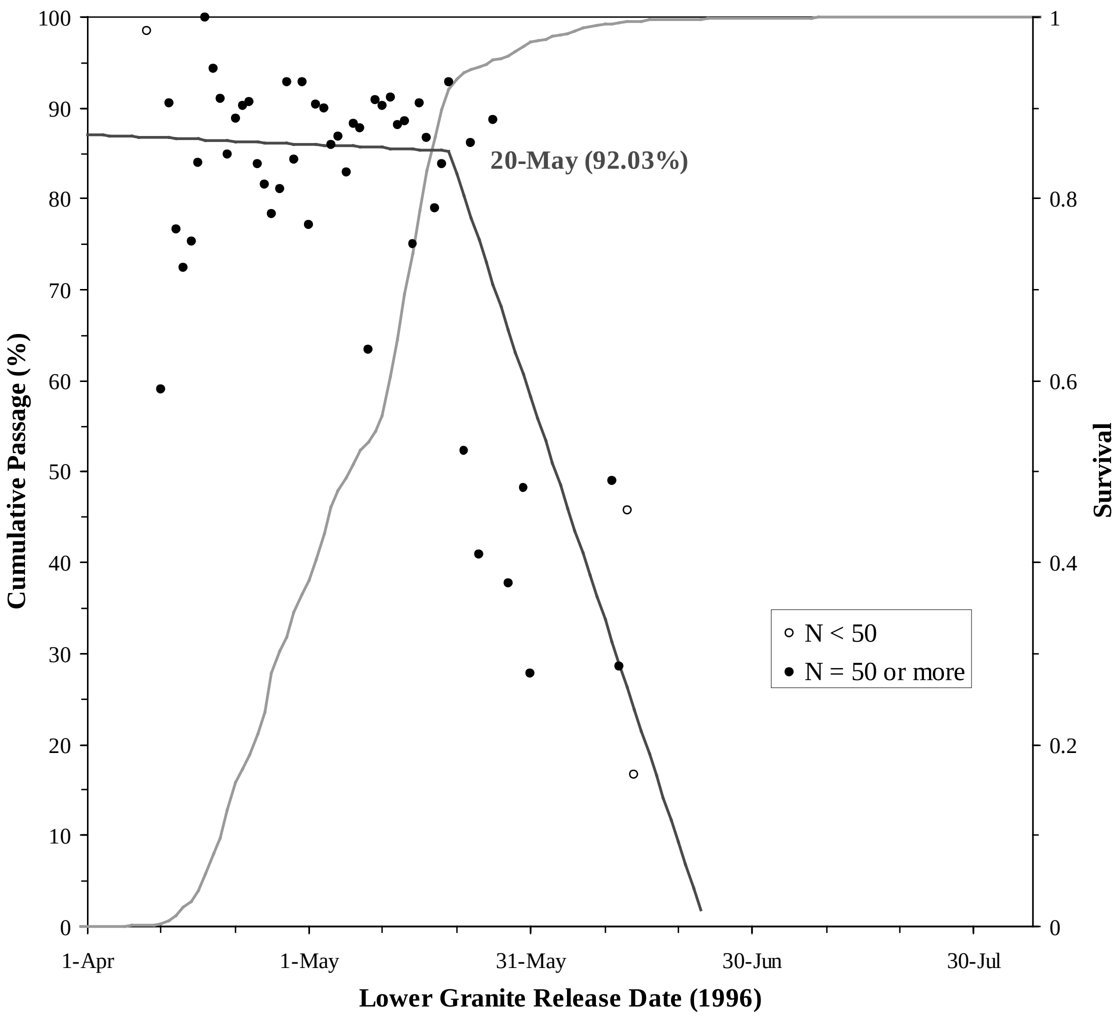


Figure 7: Spline (red line) for daily survival estimates of 1996 spring chinook smolt from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam, along with the cumulative arrival distribution at Lower Granite Dam (green line). Symbols indicate the number of fish in the release groups that the survival estimates were based upon.



May ($\hat{S}_{1.2} = 0.9044 - 0.0004D$), followed again by a pronounced decrease in survival ($\hat{S}_{1.2} = 4.3127 - 0.0245D$), with the change in trends occurring once 92.03% of the run has passed by LGR. The coefficient of determination was considerably larger than that for the 1994 data (r^2 = 0.487).

The spline for the 1995 data showed a different situation (Fig. 6). Until 28 June (99.43% of the cumulative run) survivals showed a decline according to the equation $\hat{S}_{1.2} = 1.0930 - 0.0022D$. Afterwards, survivals estimates increased following the expression $\hat{S}_{1.2} = -0.6745 + 0.0076D$. Admittedly, the fit was considerably poorer than those for the 1994 and 1996 data (r^2 = 0.089). Figure 6 clearly shows that the second, ascending portion of the 1995 spline relies almost entirely on survivals from small releases (N < 50 fish). In fact, when the survival estimates from these small-sized groups were removed from the analysis, the new 1995 spline showed a pattern similar to that of 1994: an initial increase in survival followed by a pronounced decrease. The change in slope occurs on 22 May when 92.81% of the run has passed by LGR. The new equations for the ascending and descending limbs of the spline were $\hat{S}_{1.2} = 0.6357 + 0.0016D$ and $\hat{S}_{1.2} = 1.9316 - 0.0074D$, respectively. The coefficient of determination for this new fit increased to r^2 = 0.194.

In summary, the results from the spline analyses of the 1994, 1995 and 1996 data agree with those from the previous regression analyses (Appendix A1-9, Tables 2-3). It appears to be a negative trend in survivals associated to the last days of the outmigrations (8% of the cumulative runs), a trend that may be difficult to detect if the *SURPH.1* survival estimates were based on only a few released fish.

3.3 Assessment of bias

Tables 4-9 show the summary statistics for the 1000 simulations performed to detect the effect of the number of marked fish released on *SURPH.1* survival estimates. Figure 8 illustrates the average $\hat{S}_{1.2}$ and 95% confidence intervals for these simulations.

Table 4: Effect of the number of marked fish released (N) on *SURPH.1* estimates for S_1, S_2, $S_{1.2}$, p_1, p_2 and λ. Estimates were obtained after simulating 1000 groups of 50 and 500 capture histories, assuming that $S_1 = 0.88$, $S_2 = 0.9$, $S_{1.2} = S_1 \times S_2$, and $p_1 = p_2 = \lambda = 0.4$.

		S_1	p_1	S_2	p_2	λ	$S_{1.2}$
N	True Values	***0.88***	***0.4***	***0.9***	***0.4***	***0.4***	***0.792***
50	Average	0.907	0.398	0.980	0.400	0.401	0.859
	Median	0.880	0.393	0.923	0.400	0.400	0.793
	Bias	0.027	-0.002	0.080	0.000	0.001	0.067
	% Bias	3.03	0.55	8.94	0.04	0.18	8.48
500	Average	0.882	0.400	0.910	0.399	0.399	0.800
	Median	0.881	0.401	0.906	0.399	0.397	0.795
	Bias	0.002	0.000	0.010	-0.001	-0.001	0.008
	% Bias	0.17	0.10	1.06	0.24	0.22	0.97

Table 5: Effect of the number of marked fish released (N) on *SURPH.1* estimates for S_1, S_2, $S_{1.2}$, p_1, p_2 and λ. Estimates were obtained after simulating 1000 groups of 50 and 500 capture histories, assuming that $S_1 = 0.88$, $S_2 = 0.9$, $S_{1.2} = S_1 \times S_2$, and $p_1 = p_2 = \lambda = 0.2$.

		S_1	p_1	S_2	p_2	λ	$S_{1.2}$
N	True Values	***0.88***	***0.2***	***0.9***	***0.2***	***0.2***	***0.792***
50	Average	1.003	0.241	1.048	0.250	0.249	0.916
	Median	0.900	0.231	0.896	0.229	0.231	0.800
	Bias	0.123	0.041	0.148	0.050	0.049	0.124
	% Bias	14.02	20.28	16.40	25.01	24.67	15.69
500	Average	0.897	0.201	0.951	0.199	0.198	0.837
	Median	0.882	0.200	0.914	0.200	0.197	0.798
	Bias	0.017	0.001	0.051	-0.001	-0.002	0.045
	% Bias	1.89	0.44	5.67	0.33	1.00	5.65

Table 6: Effect of the number of marked fish released (N) on *SURPH.1* estimates for S_1, S_2, $S_{1.2}$, p_1, p_2 and λ. Estimates were obtained after simulating 1000 groups of 50 and 500 capture histories, assuming that $S_1 = 0.82$, $S_2 = 0.78$, $S_{1.2} = S_1 \times S_2$, and $p_1 = p_2 = \lambda = 0.4$.

		S_1	p_1	S_2	p_2	λ	$S_{1.2}$
N	True Values	***0.82***	***0.4***	***0.78***	***0.4***	***0.4***	***0.64***
50	Average	0.865	0.400	0.866	0.397	0.396	0.716
	Median	0.835	0.400	0.800	0.400	0.387	0.653
	Bias	0.045	0.000	0.086	-0.003	-0.004	0.076
	% Bias	5.52	0.12	11.07	0.72	1.07	11.90
500	Average	0.823	0.399	0.786	0.399	0.399	0.644
	Median	0.822	0.400	0.778	0.398	0.400	0.638
	Bias	0.003	-0.001	0.006	-0.001	-0.001	0.005
	% Bias	0.42	0.29	0.74	0.35	0.22	0.75

Table 7: Effect of the number of marked fish released (N) on *SURPH.1* estimates for S_1, S_2, $S_{1.2}$, p_1, p_2 and λ. Estimates were obtained after simulating 1000 groups of 50 and 500 capture histories, assuming that $S_1 = 0.82$, $S_2 = 0.78$, $S_{1.2} = S_1 \times S_2$, and $p_1 = p_2 = \lambda = 0.2$.

		S_1	p_1	S_2	p_2	λ	$S_{1.2}$
N	True Values	***0.82***	***0.2***	***0.78***	***0.2***	***0.2***	***0.64***
50	Average	0.982	0.252	0.931	0.262	0.267	0.786
	Median	0.872	0.245	0.789	0.250	0.250	0.663
	Bias	0.162	0.052	0.151	0.062	0.067	0.146
	% Bias	19.70	25.93	19.40	31.21	33.67	22.86
500	Average	0.846	0.200	0.832	0.198	0.198	0.683
	Median	0.827	0.198	0.782	0.197	0.197	0.646
	Bias	0.026	0.000	0.052	-0.002	-0.002	0.044
	% Bias	3.16	0.04	6.61	0.84	0.92	6.85

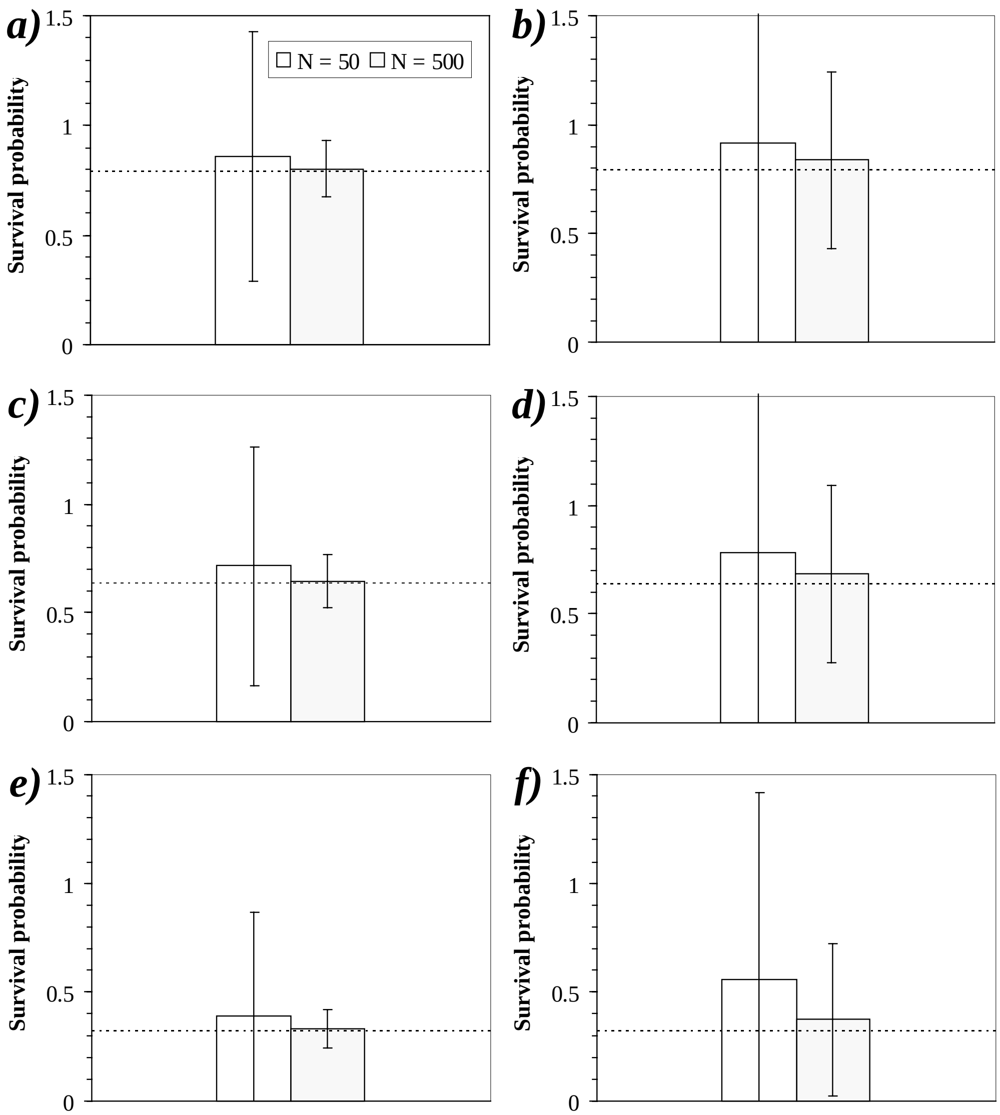
Table 8: Effect of the number of marked fish released (N) on *SURPH.1* estimates for S_1, S_2, $S_{1.2}$, p_1, p_2 and λ. Estimates were obtained after simulating 1000 groups of 50 and 500 capture histories, assuming that $S_1 = 0.64$, $S_2 = 0.51$, $S_{1.2} = S_1 \times S_2$, and $p_1 = p_2 = \lambda = 0.4$.

		S_1	p_1	S_2	p_2	λ	$S_{1.2}$
N	True Values	***0.64***	***0.4***	***0.51***	***0.4***	***0.4***	***0.326***
50	Average	0.741	0.414	0.593	0.423	0.414	0.393
	Median	0.660	0.400	0.513	0.400	0.400	0.333
	Bias	0.101	0.014	0.083	0.023	0.014	0.066
	% Bias	15.76	3.62	16.22	5.80	3.58	20.26
500	Average	0.642	0.403	0.522	0.401	0.401	0.332
	Median	0.637	0.400	0.519	0.400	0.403	0.329
	Bias	0.002	0.003	0.012	0.001	0.001	0.005
	% Bias	0.31	0.73	2.43	0.27	0.27	1.68

Table 9: Effect of the number of marked fish released (N) on *SURPH.1* estimates for S_1, S_2, $S_{1.2}$, p_1, p_2 and λ. Estimates were obtained after simulating 1000 groups of 50 and 500 capture histories, assuming that $S_1 = 0.64$, $S_2 = 0.51$, $S_{1.2} = S_1 \times S_2$, and $p_1 = p_2 = \lambda = 0.2$.

		S_1	p_1	S_2	p_2	λ	$S_{1.2}$
N	True Values	***0.64***	***0.2***	***0.51***	***0.2***	***0.2***	***0.326***
50	Average	0.865	0.307	0.722	0.295	0.294	0.560
	Median	0.784	0.286	0.571	0.250	0.250	0.420
	Bias	0.225	0.107	0.212	0.095	0.094	0.233
	% Bias	35.17	53.48	41.61	47.51	47.15	71.43
500	Average	0.679	0.201	0.584	0.200	0.200	0.373
	Median	0.650	0.196	0.504	0.200	0.198	0.328
	Bias	0.039	0.001	0.074	0.000	0.000	0.047
	% Bias	6.03	0.45	14.44	0.03	0.12	14.40

Figure 8: Effect of the number of marked fish released (N) on *SURPH.1* survival estimates for $S_{1.2}$. Bars indicate the average of 1000 estimates obtained after simulating capture histories for 50 and 500 released fish, assuming that $S_{1.2} = S_1 \times S_2$ when: ***a)*** $S_1 = 0.88$, $S_2 = 0.9$ and $p_1 = p_2 = \lambda = 0.4$; ***b)*** $S_1 = 0.88$, $S_2 = 0.9$ and $p_1 = p_2 = \lambda = 0.2$; ***c)*** $S_1 = 0.82$, $S_2 = 0.78$ and $p_1 = p_2 = \lambda = 0.4$; ***d)*** $S_1 = 0.82$, $S_2 = 0.78$ and $p_1 = p_2 = \lambda = 0.2$; ***e)*** $S_1 = 0.64$, $S_2 = 0.51$ and $p_1 = p_2 = \lambda = 0.4$ and ***f)*** $S_1 = 0.64$, $S_2 = 0.51$ and $p_1 = p_2 = \lambda = 0.2$. Errors bars indicate estimated 95% confidence intervals. Horizontal lines are $S_{1.2}$ values.



In general, there was positive bias in the estimates of survival rates (i.e., $\bar{\hat{S}}_{1.2} > S_{1.2}$), and the bias as well as the spread of the estimates were greatly reduced when the estimates were based on release groups of 500 or more fish. For release groups of 50 fish, this positive bias was larger when the parameter values were low ($p_1 = p_2 = \lambda = 0.2$; Tables 5, 7 and 9, Fig. 8 *b*, *d*, *f*). Similarly, $\hat{S}_{1.2}$ was more biased for low S_1 and S_2, in particular when low survival rates were coupled with low capture probabilities (Tables 8-9, Fig. 8 *e-f*).

The decreasing trends in survival for the second portions of the 1994, 1995 and 1996 runs (Table 3, Fig. 5-7) cannot be explained by estimation bias in the survival estimates. The expected bias in survival estimates for release groups with as few as 50 fish were always positive, and opposite to the season trend observed in survivals.

4. DISCUSSION

The present analyses suggest that temporal trends in the series of *SURPH.1* survival estimates occurred for the 1994, 1995 and 1996 spring chinook salmon outmigrations. Given the variability of daily survival estimates during the outmigration, trend analyses should consist of at least 5 or more consecutive estimates.

Second, trends, when detected, seem to have affected only the last portions (e.g. the last 50%) of the run. The trends detected for the last 50% of the 1994, 1995 and 1996 spring chinook salmon runs were always negative or decreasing trends (Tables 2-3). Negative trends were also detected for the last 2.43% and 13.25% of the 1994 and 1996 runs (Appendixes A2 and A8), and between the last 1.74% and 0.78% of the 1995 outmigration (Appendix A5). Similarly, the spline analyses suggested decreasing trends during the last 8% of the cumulative runs (Fig. 5-7). Thus, some factor or factors affecting the LGR-LMN reach may have depressed the survival of smolt released towards the end of the outmigration.

Finally, our simulations (Fig. 8) showed that *SURPH.1* survival estimates for small releases (e.g. 50 fish) are likely to be positively biased. This is the probable reason for the few $\hat{S}_{1.2}$'s greater than one encountered the last days of the 1995 run (Fig. 6).

The fact that the expected bias in the estimation of both S_1 and S_2 was always positive (Tables 4-9) gives more credance to the decreasing trends found in the data. These trends cannot be disregarded as simple artifacts of biased survival estimates. In future years it would be advisable to increase the number of tagged fish released during the last weeks of the run.

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6. APPENDICES

Estimates of temporal trends using combinations of 5, 15 and 30 survival estimates

A 1: Estimates of the slope for the regression of survival versus Day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1994, using a window of 5 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
183-159	-0.0114	0.0106	0.360	0.279
168-158	-0.0061	0.0220	0.800	0.025
167-157	-0.0058	0.0220	0.810	0.022
166-156	-0.0248	0.0218	0.339	0.300
159-153	0.0417	0.0453	0.426	0.220
158-152	-0.0604	0.0934	0.564	0.122
157-150	-0.0523	0.0840	0.577	0.115
156-148	-0.0487	0.0797	0.584	0.111
153-147	-0.0320	0.0960	0.761	0.036
152-146	0.0888	0.0556	0.209	0.460
150-144	0.0064	0.0349	0.867	0.011
148-143	-0.0894	0.0934	0.409	0.234
147-142	-0.0516	0.1086	0.668	0.070
146-141	-0.0935	0.1168	0.482	0.176
144-140	0.0323	0.1530	0.846	0.015
143-139	0.1867	0.1147	0.202	0.469
142-138	0.1011	0.0904	0.345	0.294
141-137	0.0868	0.0980	0.441	0.207
140-136	-0.0568	0.0608	0.419	0.225
139-135	-0.0578	0.0605	0.410	0.233
138-134	-0.0633	0.0601	0.369	0.270
137-133	0.0509	0.0259	0.144	0.563
136-132	0.0551	0.0266	0.130	0.589
135-131	0.0164	0.0353	0.674	0.067
134-130	0.0100	0.0365	0.802	0.024
133-129	-0.0513	0.0185	0.069	0.720
132-128	-0.0131	0.0367	0.745	0.041
131-127	-0.0003	0.0316	0.993	0.000
130-126	0.0143	0.0330	0.694	0.059
129-125	0.0234	0.0325	0.523	0.148
128-124	-0.0258	0.0304	0.458	0.194
127-123	0.0130	0.0265	0.658	0.074

A 1 (Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
126-122	-0.0107	0.0202	0.634	0.085
125-121	0.0140	0.0210	0.553	0.129
124-120	0.0392	0.0124	0.051	0.770
123-119	0.0188	0.0085	0.113	0.623
122-118	0.0217	0.0076	0.064	0.734
121-117	-0.0110	0.0118	0.419	0.225
120-116	-0.0181	0.0099	0.165	0.526
119-115	-0.0246	0.0095	0.081	0.692
118-114	-0.0199	0.0106	0.156	0.543
117-113	0.0186	0.0145	0.290	0.354
116-112	-0.0009	0.0205	0.968	0.001
115-111	-0.0062	0.0211	0.788	0.028
114-110	-0.0278	0.0191	0.241	0.415
113-109	-0.0015	0.0322	0.966	0.001
112-108	0.0178	0.0245	0.520	0.150
111-107	0.0201	0.0244	0.471	0.184
110-106	0.0957	0.0493	0.147	0.557
109-105	0.1019	0.0490	0.129	0.590

A 2: Estimates of the slope for the regression of survival versus day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1994, using a window of 15 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
183-144	-0.0163	0.0069	0.035	0.298
168-143	-0.0237	0.0108	0.046	0.271
167-142	-0.0227	0.0116	0.071	0.229
166-141	-0.0306	0.0123	0.028	0.322
159-140	-0.0260	0.0145	0.095	0.199
158-139	-0.0162	0.0151	0.304	0.081
157-138	-0.0108	0.0166	0.528	0.031
156-137	-0.0062	0.0172	0.722	0.010
153-136	-0.0009	0.0182	0.961	0.000
152-135	0.0174	0.0163	0.305	0.081
150-134	0.0023	0.0158	0.886	0.002
148-133	0.0121	0.0159	0.461	0.042
147-132	0.0140	0.0163	0.407	0.054
146-131	0.0150	0.0166	0.382	0.059
144-130	0.0211	0.0164	0.221	0.113
143-129	0.0237	0.0160	0.163	0.144
142-128	0.0061	0.0111	0.590	0.023
141-127	0.0069	0.0110	0.540	0.030
140-126	-0.0045	0.0077	0.574	0.025
139-125	-0.0030	0.0078	0.705	0.011
138-124	-0.0029	0.0078	0.716	0.011
137-123	0.0066	0.0057	0.264	0.095
136-122	0.0023	0.0052	0.668	0.015
135-121	0.0013	0.0050	0.801	0.005
134-120	0.0038	0.0051	0.476	0.040
133-119	0.0019	0.0048	0.701	0.012
132-118	0.0052	0.0047	0.287	0.087
131-117	0.0081	0.0039	0.060	0.247
130-116	0.0072	0.0040	0.092	0.203
129-115	0.0054	0.0042	0.219	0.114
128-114	0.0014	0.0038	0.719	0.010
127-113	0.0059	0.0035	0.120	0.175
126-112	0.0008	0.0034	0.825	0.004
125-111	-0.0002	0.0035	0.965	0.000
124-110	-0.0021	0.0037	0.583	0.024
123-109	-0.0027	0.0035	0.448	0.045
122-108	-0.0040	0.0035	0.273	0.091

A 2(Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
121-107	-0.0044	0.0034	0.216	0.115
120-106	0.0068	0.0073	0.373	0.062
119-105	0.0161	0.0082	0.072	0.228

A 3: Estimates of the slope for the regression of survival versus day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1994, using a window of 30 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
183-129	-0.0099	0.0040	0.019	0.180
168-128	-0.0067	0.0045	0.144	0.075
167-127	-0.0066	0.0047	0.166	0.067
166-126	-0.0060	0.0049	0.232	0.051
159-125	-0.0030	0.0051	0.557	0.012
158-124	-0.0008	0.0050	0.874	0.001
157-123	-0.0004	0.0051	0.936	0.000
156-122	0.0021	0.0051	0.688	0.006
153-121	0.0044	0.0052	0.400	0.025
152-120	0.0094	0.0046	0.050	0.130
150-119	0.0058	0.0042	0.180	0.063
148-118	0.0079	0.0042	0.071	0.112
147-117	0.0068	0.0042	0.115	0.086
146-116	0.0069	0.0042	0.111	0.088
144-115	0.0078	0.0042	0.073	0.110
143-114	0.0085	0.0041	0.048	0.132
142-113	0.0037	0.0028	0.201	0.058
141-112	0.0040	0.0028	0.161	0.069
140-111	0.0004	0.0021	0.838	0.002
139-110	0.0000	0.0021	0.989	0.000
138-109	0.0013	0.0021	0.549	0.013
137-108	0.0030	0.0017	0.086	0.102
136-107	0.0020	0.0016	0.218	0.054
135-106	0.0039	0.0022	0.078	0.107
134-105	0.0062	0.0024	0.016	0.189

A 4: Estimates of the slope for the regression of survival versus day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1995, using a window of 5 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
214-192	0.0009	0.0131	0.948	0.002
204-191	-0.0238	0.0173	0.263	0.387
195-190	-0.0111	0.0603	0.865	0.011
193-189	0.0485	0.0669	0.521	0.149
192-188	0.0953	0.0456	0.128	0.593
191-187	-0.0564	0.0613	0.426	0.220
190-186	-0.0426	0.0683	0.577	0.115
189-185	0.0553	0.0781	0.530	0.143
188-184	0.0409	0.0825	0.654	0.076
187-183	0.0778	0.0767	0.385	0.255
186-182	-0.0158	0.0456	0.752	0.038
185-181	0.0206	0.0531	0.724	0.048
184-180	0.0926	0.0205	0.020	0.871
183-179	-0.0144	0.0504	0.794	0.026
182-178	-0.0558	0.0489	0.337	0.302
181-177	-0.0590	0.0475	0.302	0.340
180-176	-0.0001	0.0537	0.999	0.000
179-175	0.0704	0.0158	0.021	0.869
178-174	0.0047	0.0416	0.917	0.004
177-173	-0.0218	0.0314	0.538	0.138
176-172	-0.0066	0.0354	0.864	0.011
175-171	-0.0013	0.0342	0.972	0.000
174-170	0.0218	0.0280	0.493	0.168
173-169	-0.0003	0.0180	0.988	0.000
172-168	-0.0246	0.0230	0.363	0.276
171-167	-0.0036	0.0217	0.879	0.009
170-166	-0.0021	0.0221	0.930	0.003
169-165	0.0030	0.0223	0.902	0.006
168-164	0.0299	0.0102	0.060	0.743
167-163	-0.0215	0.0206	0.374	0.266
166-162	-0.0123	0.0243	0.647	0.079
165-161	-0.0294	0.0267	0.351	0.288
164-160	-0.0390	0.0267	0.240	0.416
163-159	-0.0046	0.0284	0.882	0.009
162-158	-0.0215	0.0251	0.455	0.196
161-157	-0.0019	0.0162	0.914	0.005
160-156	-0.0165	0.0166	0.393	0.248

A 4 (Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
159-155	-0.0098	0.0204	0.663	0.072
158-154	0.0146	0.0162	0.434	0.213
157-153	0.0196	0.0143	0.263	0.386
156-152	0.0326	0.0163	0.140	0.570
155-151	0.0225	0.0143	0.213	0.453
154-150	0.0309	0.0117	0.078	0.698
153-149	-0.0234	0.0365	0.567	0.121
152-148	-0.0545	0.0261	0.128	0.593
151-147	-0.0215	0.0373	0.604	0.100
150-146	0.0082	0.0361	0.835	0.017
149-145	0.0308	0.0244	0.295	0.348
148-144	-0.0327	0.0284	0.333	0.306
147-143	-0.3178	0.1383	0.105	0.638
146-142	-0.1621	0.2024	0.482	0.176
145-141	0.0078	0.2188	0.974	0.000
144-140	0.1537	0.1974	0.493	0.168
143-139	0.2837	0.1519	0.159	0.538
142-138	0.0202	0.0108	0.158	0.539
141-137	0.0142	0.0115	0.304	0.338
140-136	0.0026	0.0153	0.876	0.009
139-135	-0.0453	0.0136	0.045	0.786
138-134	-0.0323	0.0194	0.195	0.480
137-133	0.0125	0.0319	0.721	0.049
136-132	0.0383	0.0253	0.227	0.433
135-131	0.0283	0.0298	0.413	0.231
134-130	-0.0144	0.0215	0.551	0.130
133-129	-0.0304	0.0133	0.107	0.634
132-128	0.0031	0.0160	0.858	0.012
131-127	0.0166	0.0088	0.157	0.540
130-126	0.0009	0.0124	0.947	0.002
129-125	-0.0103	0.0100	0.379	0.261
128-124	-0.0153	0.0078	0.146	0.560
127-123	-0.0013	0.0044	0.787	0.028
126-122	0.0044	0.0014	0.055	0.759
125-121	0.0044	0.0014	0.055	0.759
124-120	0.0017	0.0024	0.529	0.144
123-119	-0.0067	0.0051	0.284	0.361

A 4 (Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
122-118	-0.0108	0.0044	0.089	0.672
121-117	-0.0053	0.0071	0.511	0.156
120-116	0.0004	0.0060	0.951	0.001
119-115	0.0127	0.0048	0.077	0.701
118-114	0.0019	0.0085	0.838	0.016
117-113	0.0010	0.0083	0.911	0.005
116-112	-0.0003	0.0084	0.974	0.000
115-111	-0.0011	0.0083	0.902	0.006
114-110	0.0015	0.0072	0.849	0.014
113-109	-0.0121	0.0049	0.090	0.670
112-108	-0.0112	0.0049	0.106	0.636
111-107	-0.0107	0.0051	0.129	0.591
110-106	0.0080	0.0073	0.353	0.286
109-105	0.0108	0.0061	0.175	0.511
108-104	0.0197	0.0072	0.072	0.712
107-103	0.0233	0.0074	0.051	0.769
106-102	0.0189	0.0077	0.091	0.669
105-101	0.0025	0.0154	0.881	0.009
104-100	-0.0678	0.0300	0.109	0.630
103-99	-0.0261	0.0498	0.636	0.084

A 5: Estimates of the slope for the regression of survival versus day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1995, using a window of 15 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
214-182	0.0058	0.0059	0.347	0.068
204-181	0.0056	0.0088	0.533	0.031
195-180	0.0215	0.0107	0.066	0.237
193-179	0.0216	0.0111	0.073	0.226
192-178	0.0209	0.0112	0.085	0.211
191-177	0.0125	0.0102	0.241	0.104
190-176	0.0109	0.0100	0.297	0.083
189-175	0.0151	0.0098	0.147	0.155
188-174	0.0110	0.0103	0.306	0.080
187-173	0.0109	0.0103	0.310	0.079
186-172	0.0008	0.0076	0.915	0.001
185-171	-0.0009	0.0076	0.911	0.001
184-170	0.0031	0.0072	0.671	0.014
183-169	-0.0009	0.0064	0.884	0.002
182-168	-0.0038	0.0065	0.570	0.025
181-167	-0.0050	0.0065	0.456	0.043
180-166	-0.0002	0.0061	0.979	0.000
179-165	0.0055	0.0051	0.293	0.084
178-164	0.0025	0.0046	0.593	0.023
177-163	-0.0046	0.0044	0.314	0.078
176-162	-0.0031	0.0045	0.498	0.036
175-161	-0.0040	0.0046	0.408	0.053
174-160	-0.0050	0.0048	0.316	0.077
173-159	-0.0089	0.0039	0.040	0.285
172-158	-0.0098	0.0039	0.027	0.323
171-157	-0.0099	0.0039	0.026	0.328
170-156	-0.0132	0.0038	0.004	0.482
169-155	-0.0118	0.0040	0.012	0.399
168-154	-0.0089	0.0040	0.047	0.271
167-153	-0.0107	0.0037	0.013	0.390
166-152	-0.0071	0.0044	0.131	0.167
165-151	-0.0025	0.0046	0.605	0.021
164-150	0.0021	0.0046	0.650	0.016
163-149	0.0013	0.0049	0.799	0.005
162-148	-0.0012	0.0050	0.814	0.004
161-147	0.0042	0.0045	0.367	0.063
160-146	0.0043	0.0045	0.354	0.066

A 5 (Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
159-145	0.0016	0.0045	0.735	0.009
158-144	-0.0017	0.0052	0.754	0.008
157-143	-0.0370	0.0207	0.097	0.197
156-142	-0.0354	0.0209	0.114	0.181
155-141	-0.0334	0.0212	0.139	0.160
154-140	-0.0294	0.0215	0.195	0.125
153-139	-0.0232	0.0221	0.313	0.078
152-138	-0.0180	0.0225	0.439	0.047
151-137	-0.0097	0.0227	0.675	0.014
150-136	-0.0025	0.0226	0.914	0.001
149-135	0.0025	0.0222	0.912	0.001
148-134	0.0044	0.0222	0.847	0.003
147-133	0.0117	0.0222	0.608	0.021
146-132	0.0209	0.0216	0.350	0.067
145-131	0.0273	0.0208	0.213	0.117
144-130	0.0322	0.0202	0.136	0.163
143-129	0.0339	0.0200	0.115	0.180
142-128	0.0012	0.0036	0.756	0.008
141-127	0.0003	0.0036	0.941	0.000
140-126	-0.0005	0.0036	0.899	0.001
139-125	-0.0021	0.0035	0.558	0.027
138-124	-0.0010	0.0035	0.773	0.007
137-123	0.0001	0.0034	0.977	0.000
136-122	0.0011	0.0033	0.735	0.009
135-121	0.0012	0.0033	0.721	0.010
134-120	-0.0027	0.0023	0.262	0.096
133-119	-0.0047	0.0021	0.046	0.272
132-118	-0.0028	0.0017	0.120	0.176
131-117	-0.0009	0.0015	0.529	0.031
130-116	-0.0020	0.0013	0.153	0.150
129-115	-0.0018	0.0014	0.204	0.121
128-114	-0.0026	0.0014	0.086	0.209
127-113	-0.0003	0.0011	0.800	0.005
126-112	0.0000	0.0011	0.979	0.000
125-111	0.0001	0.0011	0.944	0.000
124-110	-0.0004	0.0011	0.740	0.009
123-109	-0.0012	0.0012	0.345	0.069

A 5 (Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
122-108	-0.0019	0.0013	0.169	0.140
121-107	-0.0021	0.0013	0.130	0.168
120-106	-0.0006	0.0014	0.683	0.013
119-105	-0.0003	0.0014	0.819	0.004
118-104	0.0007	0.0016	0.686	0.013
117-103	0.0020	0.0019	0.319	0.076
116-102	0.0039	0.0020	0.078	0.219
115-101	0.0029	0.0021	0.192	0.127
114-100	-0.0028	0.0046	0.556	0.027
113-99	-0.0004	0.0049	0.943	0.000

A 6: Estimates of the slope for the regression of survival versus day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1995, using a window of 30 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
214-167	0.0063	0.0026	0.021	0.175
204-166	0.0053	0.0030	0.082	0.104
195-165	0.0071	0.0031	0.029	0.159
193-164	0.0077	0.0031	0.019	0.182
192-163	0.0069	0.0031	0.035	0.149
191-162	0.0044	0.0028	0.122	0.083
190-161	0.0023	0.0028	0.419	0.023
189-160	0.0016	0.0028	0.563	0.012
188-159	0.0012	0.0028	0.684	0.006
187-158	0.0002	0.0028	0.955	0.000
186-157	-0.0038	0.0021	0.085	0.102
185-156	-0.0048	0.0021	0.035	0.149
184-155	-0.0038	0.0021	0.080	0.105
183-154	-0.0054	0.0019	0.007	0.231
182-153	-0.0056	0.0018	0.005	0.250
181-152	-0.0053	0.0019	0.009	0.221
180-151	-0.0038	0.0019	0.052	0.128
179-150	-0.0020	0.0018	0.273	0.043
178-149	-0.0040	0.0017	0.028	0.160
177-148	-0.0054	0.0016	0.003	0.281
176-147	-0.0048	0.0017	0.008	0.227
175-146	-0.0039	0.0017	0.027	0.163
174-145	-0.0035	0.0016	0.042	0.140
173-144	-0.0054	0.0016	0.002	0.286
172-143	-0.0141	0.0053	0.013	0.200
171-142	-0.0132	0.0054	0.021	0.177
170-141	-0.0127	0.0054	0.026	0.165
169-140	-0.0122	0.0054	0.032	0.153
168-139	-0.0105	0.0055	0.065	0.117
167-138	-0.0100	0.0055	0.080	0.105
166-137	-0.0090	0.0056	0.118	0.085
165-136	-0.0079	0.0056	0.165	0.068
164-135	-0.0077	0.0056	0.178	0.064
163-134	-0.0065	0.0056	0.256	0.046
162-133	-0.0054	0.0056	0.346	0.032
161-132	-0.0036	0.0056	0.529	0.014
160-131	-0.0035	0.0056	0.543	0.013

A 6 (Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
159-130	-0.0034	0.0056	0.547	0.013
158-129	-0.0025	0.0056	0.656	0.007
157-128	-0.0016	0.0057	0.777	0.003
156-127	-0.0014	0.0057	0.809	0.002
155-126	-0.0015	0.0057	0.791	0.003
154-125	-0.0008	0.0056	0.895	0.001
153-124	-0.0001	0.0056	0.990	0.000
152-123	0.0005	0.0056	0.934	0.000
151-122	0.0018	0.0056	0.745	0.004
150-121	0.0034	0.0055	0.548	0.013
149-120	0.0049	0.0054	0.374	0.028
148-119	0.0046	0.0054	0.402	0.025
147-118	0.0049	0.0054	0.373	0.028
146-117	0.0063	0.0053	0.247	0.047
145-116	0.0074	0.0052	0.169	0.067
144-115	0.0083	0.0052	0.120	0.084
143-114	0.0079	0.0052	0.138	0.077
142-113	-0.0008	0.0009	0.420	0.023
141-112	-0.0010	0.0009	0.264	0.044
140-111	-0.0009	0.0009	0.333	0.034
139-110	-0.0013	0.0009	0.160	0.069
138-109	-0.0012	0.0009	0.199	0.058
137-108	-0.0011	0.0009	0.235	0.050
136-107	-0.0009	0.0009	0.302	0.038
135-106	-0.0008	0.0009	0.374	0.028
134-105	-0.0017	0.0007	0.014	0.197
133-104	-0.0015	0.0007	0.037	0.146
132-103	-0.0003	0.0007	0.645	0.008
131-102	0.0006	0.0006	0.388	0.027
130-101	0.0003	0.0006	0.651	0.007
129-100	-0.0014	0.0011	0.217	0.054
128-99	-0.0007	0.0012	0.577	0.011

A 7: Estimates of the slope for the regression of survival versus day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1996, using a window of 5 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
166-152	0.0024	0.0136	0.870	0.010
165-151	0.0017	0.0089	0.858	0.012
164-149	-0.0004	0.0083	0.969	0.001
163-147	-0.0107	0.0205	0.637	0.084
152-145	-0.0342	0.0431	0.485	0.173
151-144	-0.0403	0.0447	0.435	0.213
149-143	-0.0196	0.0578	0.756	0.037
147-142	-0.1020	0.1266	0.479	0.178
145-141	-0.1779	0.1357	0.281	0.364
144-140	-0.0360	0.1429	0.817	0.021
143-139	0.0228	0.1457	0.886	0.008
142-138	0.1603	0.0808	0.141	0.568
141-137	0.0016	0.0201	0.942	0.002
140-136	0.0060	0.0223	0.805	0.024
139-135	-0.0074	0.0240	0.778	0.031
138-134	-0.0006	0.0226	0.981	0.000
137-133	-0.0143	0.0229	0.577	0.115
136-132	-0.0332	0.0148	0.110	0.628
135-131	-0.0068	0.0032	0.126	0.597
134-130	0.0497	0.0332	0.231	0.428
133-129	0.0337	0.0392	0.454	0.197
132-128	0.0071	0.0424	0.878	0.009
131-127	-0.0089	0.0404	0.840	0.016
130-126	-0.0421	0.0298	0.253	0.399
129-125	0.0050	0.0072	0.539	0.137
128-124	-0.0063	0.0089	0.530	0.143
127-123	-0.0180	0.0041	0.023	0.863
126-122	0.0150	0.0173	0.451	0.199
125-121	-0.0011	0.0225	0.964	0.001
124-120	0.0087	0.0224	0.724	0.048
123-119	-0.0121	0.0237	0.645	0.080
122-118	-0.0078	0.0254	0.779	0.031
121-117	0.0322	0.0159	0.137	0.577
120-116	0.0199	0.0168	0.321	0.319
119-115	0.0177	0.0176	0.388	0.253
118-114	-0.0246	0.0093	0.078	0.699
117-113	-0.0327	0.0055	0.010	0.921

A 7 (Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
116-112	-0.0210	0.0087	0.095	0.659
115-111	-0.0004	0.0115	0.974	0.000
114-110	0.0047	0.0087	0.628	0.088
113-109	-0.0103	0.0110	0.417	0.227
112-108	-0.0316	0.0100	0.051	0.767
111-107	-0.0072	0.0240	0.784	0.029
110-106	0.0415	0.0252	0.198	0.474
109-105	0.0684	0.0178	0.031	0.831
108-104	0.0582	0.0226	0.082	0.689
107-103	-0.0143	0.0255	0.614	0.095
106-102	0.0147	0.0402	0.739	0.043
105-101	-0.0633	0.0652	0.403	0.239
104-100	-0.0660	0.0650	0.385	0.256

A 8: Estimates of the slope for the regression of survival versus day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1996, using a window of 15 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
166-139	-0.0238	0.0080	0.011	0.405
165-138	-0.0222	0.0085	0.021	0.344
164-137	-0.0251	0.0092	0.017	0.364
163-136	-0.0234	0.0110	0.052	0.260
152-135	-0.0318	0.0141	0.042	0.281
151-134	-0.0235	0.0145	0.129	0.168
149-133	-0.0186	0.0154	0.249	0.101
147-132	-0.0071	0.0152	0.647	0.017
145-131	-0.0094	0.0155	0.554	0.028
144-130	0.0094	0.0140	0.515	0.033
143-129	0.0099	0.0140	0.490	0.037
142-128	0.0201	0.0116	0.107	0.187
141-127	0.0021	0.0048	0.670	0.014
140-126	-0.0005	0.0047	0.920	0.001
139-125	-0.0004	0.0047	0.927	0.001
138-124	0.0001	0.0046	0.986	0.000
137-123	-0.0014	0.0046	0.773	0.007
136-122	-0.0005	0.0048	0.924	0.001
135-121	0.0005	0.0046	0.918	0.001
134-120	0.0003	0.0046	0.943	0.000
133-119	-0.0020	0.0047	0.680	0.013
132-118	-0.0020	0.0047	0.669	0.015
131-117	-0.0015	0.0047	0.750	0.008
130-116	-0.0024	0.0046	0.607	0.021
129-115	0.0036	0.0029	0.224	0.111
128-114	0.0017	0.0031	0.579	0.024
127-113	-0.0001	0.0032	0.987	0.000
126-112	0.0001	0.0032	0.981	0.000
125-111	0.0003	0.0032	0.930	0.001
124-110	-0.0009	0.0032	0.797	0.005
123-109	-0.0038	0.0033	0.275	0.091
122-108	-0.0081	0.0033	0.031	0.309
121-107	-0.0043	0.0035	0.244	0.103
120-106	-0.0025	0.0040	0.538	0.030
119-105	0.0018	0.0046	0.711	0.011
118-104	0.0021	0.0047	0.662	0.015

A 8 (Cont.)

Days of Releases	Slope	Standard Error	P-value	r^2
117-103	0.0018	0.0047	0.713	0.011
116-102	0.0104	0.0056	0.086	0.210
115-101	0.0040	0.0077	0.610	0.021
114-100	0.0017	0.0080	0.835	0.003

A 9: Estimates of the slope for the regression of survival versus day of release for chinook salmon smolts from the tailrace of Lower Granite Dam to the tailrace of Lower Monumental Dam in 1996, using a window of 30 data points. Shadowed cells indicate slopes significantly different from 0 ($\alpha = 0.05$).

Days of Releases	Slope	Standard Error	P-value	r^2
166-124	-0.0150	0.0034	0.000	0.414
165-123	-0.0133	0.0035	0.001	0.341
164-122	-0.0125	0.0038	0.002	0.285
163-121	-0.0108	0.0040	0.012	0.207
152-120	-0.0098	0.0044	0.034	0.150
151-119	-0.0069	0.0042	0.115	0.086
149-118	-0.0042	0.0042	0.322	0.035
147-117	-0.0004	0.0039	0.917	0.000
145-116	-0.0004	0.0039	0.922	0.000
144-115	0.0028	0.0035	0.431	0.022
143-114	0.0026	0.0035	0.467	0.019
142-113	0.0047	0.0031	0.137	0.077
141-112	-0.0003	0.0014	0.858	0.001
140-111	-0.0007	0.0014	0.621	0.009
139-110	-0.0009	0.0014	0.511	0.016
138-109	-0.0010	0.0014	0.478	0.018
137-108	-0.0019	0.0014	0.197	0.059
136-107	-0.0020	0.0014	0.175	0.065
135-106	-0.0005	0.0015	0.747	0.004
134-105	0.0003	0.0016	0.855	0.001
133-104	0.0007	0.0016	0.646	0.008
132-103	0.0000	0.0016	0.977	0.000
131-102	0.0014	0.0019	0.452	0.020
130-101	-0.0008	0.0022	0.709	0.005
129-100	-0.0002	0.0021	0.935	0.000